NASA
National Aeronautics and
Space Administration

Information Summaries

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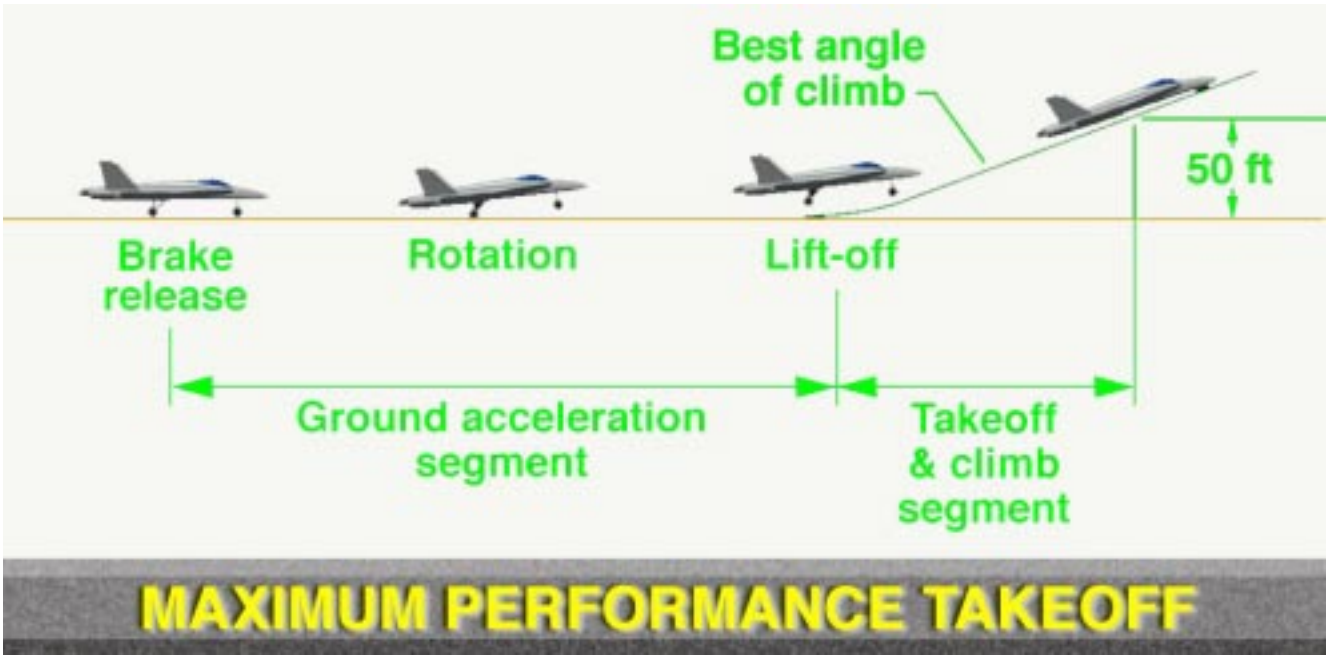
# Maximum Performance Takeoff

## Background

The takeoff is a critical maneuver in any airplane. The airplane will usually be carrying a payload (passengers, cargo, weapons) and often a full load of fuel. The resulting heavy weight means that a high speed must be reached before the wings can generate sufficient lift, thus a long distance must be travelled on the runway before lift-off. After lift-off, the heavy weight will result in a relatively slow acceleration to the speed for best angle of climb. There are several other takeoff tests that will determine emergency procedures (Refused Takeoffs, Engine-Out Takeoffs, Minimum Engine-Out Control Speeds, Soft Field Takeoffs, etc.).

The Maximum Performance Takeoff test is a non-emergency test that will determine the best takeoff technique and the length of runway required to accomplish a successful takeoff at a specific takeoff weight. It is strongly influenced by piloting technique, field elevation and atmospheric temperature. The takeoff maneuver is divided into two segments; the ground acceleration segment, and the takeoff and climb segment.



Different techniques will be tried during portions of some takeoffs to determine the optimum technique for each segment. For example, one takeoff roll will be initiated with the pitch control held in the full aft position until after nosewheel lift-off. This test will determine the slowest speed that the nosewheel can be raised (best rotation speed). The actual technique for a maximum performance takeoff would be to hold the elevator at zero to minimize drag until the best rotation speed is reached. Then full elevator would be applied to raise the nose to the optimum attitude for takeoff. Various climb speeds and gear and flap retraction methods will also be tried to optimize the airborne segment of the climb to 50 feet altitude. These tests will determine a speed for best angle of climb (which is usually somewhat slower than the speed for best rate of climb). Once the best piloting techniques for the individual segments of the takeoff are defined, the complete maximum performance takeoff test will be performed.

**1. Specific Objective of the Test**

The primary purpose of the max performance takeoff test is to establish a piloting technique that will minimize the distance that the aircraft will travel along the runway before it reaches an altitude sufficient to clear a 50-foot-high obstacle, then measure that distance for a particular weight. The results of these tests will help the users of the airplane to establish the minimum runway length that the airplane can be operated from safely.

**2. Critical Flight Condition**

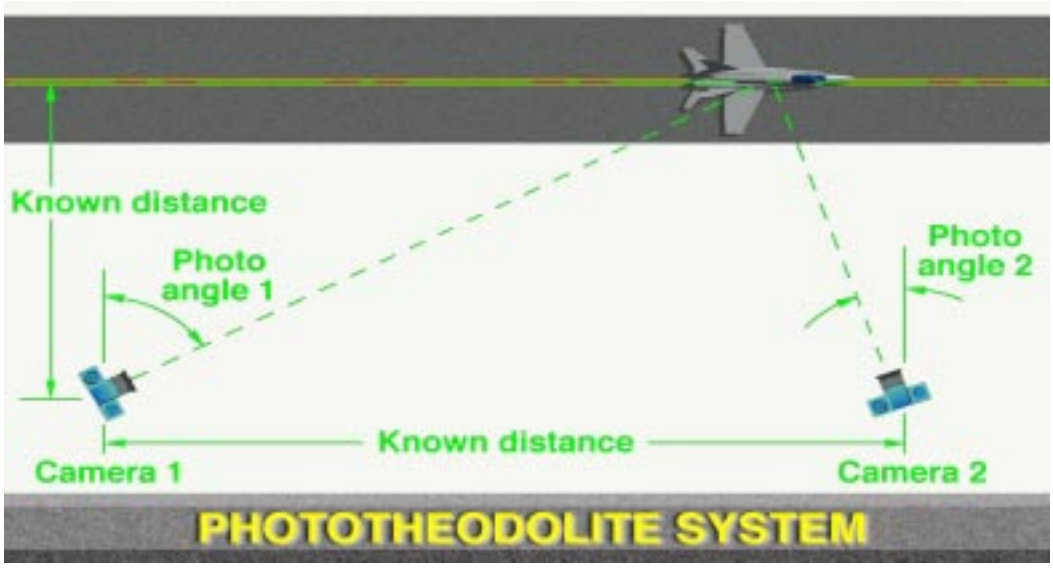
The most critical conditions for a max performance takeoff test are:

- Weight (Maximum allowable - must be accurately known.)
- Atmospheric Temperature - (Affects thrust available)
- Field Elevation - (Affects thrust and takeoff speed)
- Surface winds - (as close as possible to zero wind)

**3. Required Instrumentation**

The parameters usually measured and recorded during a maximum performance takeoff are shown in Table (1-1). The engine instruments shown are representative but not complete. The engine instrumentation will be used to correct the thrust and fuel flow data to standard day pressures and temperatures.

The normal pressure altitude measurements do not provide sufficient accuracy to locate the point in the takeoff



that the airplane has reached exactly 50 feet in altitude. Several measurement techniques have been developed for determining both the distance along the runway and the altitude above the runway. Phototheodolite measurements are photos taken of the airplane during the takeoff using several cameras in fixed locations. The cameras are linked together and have been carefully calibrated so that the image of the airplane in the photos can be used in a triangulation process to accurately determine both the location of the airplane along the runway and its altitude after takeoff.
In recent years the phototheodolite method has been augmented or replaced by on-board inertial measurements and a radar altimeter to determine location and altitude above the runway.

A continuous time history of these parameters is needed throughout the actual maneuver which usually begins at brake release. A sampling rate of at least 10 data samples every second is necessary to accurately record the maneuver, and each data sample must be accurately time correlated with the data samples of the other parameters. If photothoedolite methods are used, an accurate time correlation must be established between the on-board instrumentation measurements and the external phototheodolite measurements. That is, we must be able to relate a particular measurement of airspeed and time-from-brake-release with a measurement of runway location and altitude above the runway.

There are several key events during the takeoff that must be accurately identified both in time from brake release and distance from the start of the takeoff. They are:

- Start of rotation - (on-board pitch rate)
- Nosewheel lift-off - (photos or shock strut extension)
- Main wheel lift-off - (photos or shock strut extension)
- Altitude of 50 feet - (photos or radar altimeter)

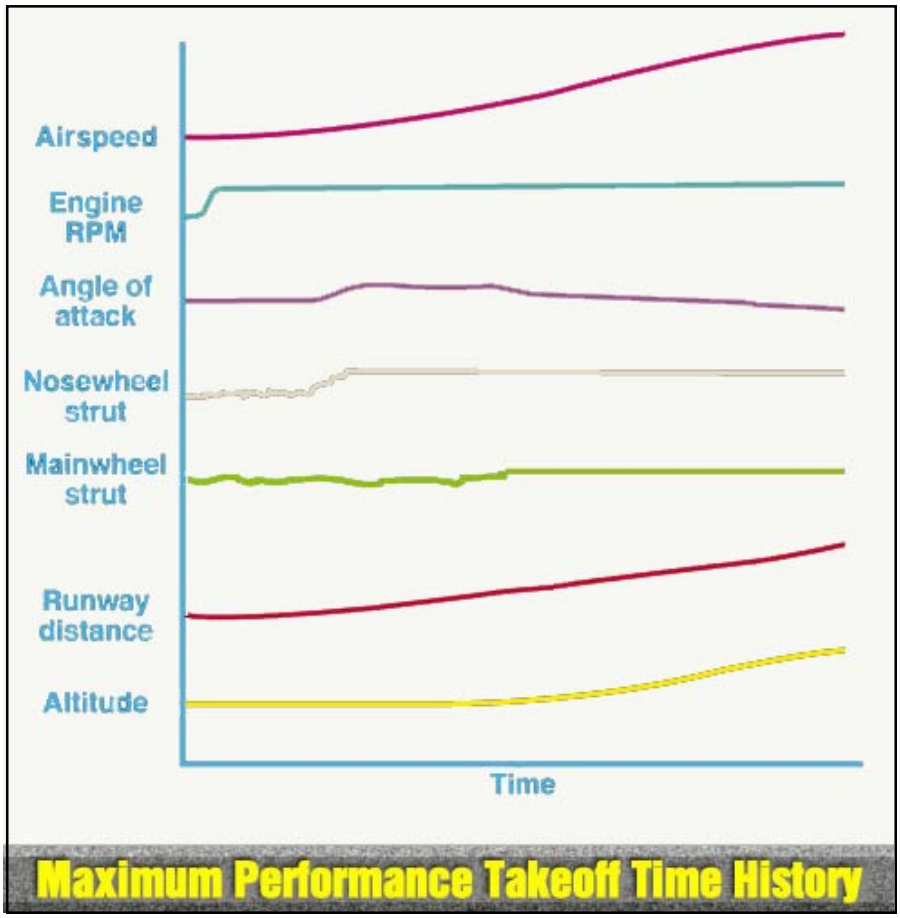
Once the time for each of these events is accurately identified, the engine data, airspeeds, etc. can be accurately calculated.

**4. Starting Trim Point**
The starting point for a max performance takeoff is brake release at the start of the takeoff roll. All measurements must be correlated to the time-of-day and aircraft location on the runway for the instant of brake release.

**5. Description of a Maximum Performance Takeoff**
The test begins on the runway by establishing Military Power with the brakes on. Time starts when the brakes are released. If the takeoff is to be in afterburner, the afterburner is ignited simultaneously with brake release. The pilot will use whatever technique had been selected for the ground acceleration segment of the takeoff (that is flap settings, control settings, steering technique, etc.). When the airplane has accelerated to the best rotation speed, the pilot will apply elevator control to place the airplane in the best attitude for takeoff. When the airplane becomes airborne the pilot will control to the speed for best angle of climb. The previously developed optimum flap retraction technique will be employed and, for most airplanes, the landing gear will be retracted immediately. (On some aircraft the drag is higher during the gear retraction cycle than it is with the gear in the down position. For these aircraft the optimum technique would be to leave the gear down during the climb segment.) After climbing past the 50 foot altitude point the pilot will continue the acceleration and climb in the normal fashion.

**6. Measures of Success**
A successful maximum performance takeoff test will meet the following test criteria:

- All instrumented parameters recorded properly.
- The weight at brake release was accurately known.
- The rotation maneuver was smooth and at the proper speed.


Airspeed
Engine RPM
Angle of attack
Nosewheel strut
Mainwheel strut
Runway distance
Altitude
Time
Maximum Performance Takeoff Time History

| Parameter | Used for |
|---|---|
| Airspeed | Compute Mach and dyn. pres. |
| Pressure Altitude | |
| Outside Air Temperature | |
| Engine tailpipe pres. & temp. | Thrust corrections to standard-day conditions |
| Engine inlet pres. & temp. | |
| Engine inlet pres. & tmep. | |
| Fuel Flow | Compute fuel Used |
| Radiosonde (weather balloon) | Wind and temp. corrections to standard day |
| Main, nose wheel shock strut position | Main and nose wheel lift-off |
| Inertial or Phototheodolite | Measurements of distance along the runway |
| Radar altimeter or Phototheodolite | Measurements of altitude above the runway |